THE TARGET* PROJECT

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The TARGET project is a cooperative undertaking of almost thirty gas companies who are financing massive research to try to develop an economical natural gas fuel cell to provide a competitive answer to the all-electric home. The objective is a power plant of a size and capability that will service not only a single family dwelling but also multi-family units, such as apartments and town house groupings, shopping centers, commercial establishments, and light industry facilities.

The sponsoring gas companies are providing up to $5 million annually in this venture with Pratt & Whitney Aircraft Division of United Aircraft Corporation, which in turn is using, as a subcontractor, the Institute of Gas Technology, the gas industry's research facility in Chicago. Pratt & Whitney is contributing another $2 million annually to the effort. With three years of study involved in Phase I of the program, a $21 million effort is scheduled, without question the largest single research effort ever undertaken by the gas industry.

While the fuel cell principle has been known for more than a century--Sir William Grove probably invented the first true fuel cell about 1840--it was confined to the laboratory until The Space Age. The fuel cell became a household word with the successful Gemini space probes which depended for electrical energy on a highly improved Grove-type fuel cell. In this cell, pure hydrogen is the fuel and pure oxygen the oxidant using an electrode catalyzed with platinum.

Natural gas is a good source of hydrogen, and air is a good source of oxygen. The problem and challenge is the right combination of these source materials to produce an economic unit not requiring an expensive catalyst. This, then, together with a detailed market analysis, constitutes the substance of the TARGET project.

In addition to the cell itself, complete systems will have to be investigated. Reformers to produce hydrogen from natural gas, methods of conditioning the air, or means of using either as is--or either substance only slightly modified--must be researched. Inverters are also being studied to determine the most efficient, the most economical, and the most long-lived type or types. Progress has been made on these approaches, but much more is necessary. This is a major part of the research program.

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* Team to Advance Research for Gas Energy Transformation, Inc.

Our research program is looking at three general groups of cells, fueled with natural gas and air, to determine which may have the best capability for success. These types may be referred to as:

1. Low temperature cells - 140°-300° F.

   a. Acid electrolytes, i.e., sulphuric or phosphoric

   b. Alkali electrolytes, i.e., sodium or potassium hydroxide

   Each of these has pros and cons. The acid cell seems unaffected by the CO_2 in the air and it appears that there is less chance of electrode pollution with insoluble carbonates. The alkaline cell appears a more efficient air electrode with less corrosion complications than the acid cell.

   Both now use rather expensive catalysts, such as platinum or silver palladium, and poison sensitivity (CO_2-H_2S) of the catalyst may be a problem.

   Here research will be directed towards the development of inexpensive catalysts with tolerance for impurities in the gases.

2. Molten-electrolyte cells

   a. Hydrate of potassium hydroxide
   (medium temperature - 400° F.)

   Requires reformers to provide hydrogen from the natural gas and equipment to remove CO_2 from the air.

   b. Molten carbonate
   (high temperature - 900°-1400° F. range)

   (1) Does not require noble metal electrode catalysts

   (2) Provides useful heat, but is sluggish in performance and has corrosion problems.

3. Solid electrolyte cells, using stabilized zirconia as the electrolyte, is the last type of cell under investigation. This is a high temperature cell operating in the 1600°-1900° F. range. Because the solid electrolyte must be thin (0.016 in.), structural problems present themselves. Plusses, however, include (1) usable waste heat, and (2) large tolerance to impurities in the reactant gases.

In our efforts, whole systems, not just the cells, must be considered--such as reformers for fuels and oxidant purification, where necessary, means of overcoming sluggishness to load demands, etc. Solution of these problems is the major effort of the TARGET research program.

Additional aspects of the research will deal with:

1. Market analysis (types of customers to be served)
2. Load characteristics
3. Methods of placing the fuel cell in the hands of the public
4. Other special interests.

This is the TARGET story.

I wish I could promise its resounding success, but in any research venture the possibility of failure always exists, of course. However, we think TARGET is not only a worthwhile business venture but one that must be undertaken if the gas industry is to continue as a leader in the primary energy business. As I said at the start, almost thirty major gas companies have laid their money on the line--not only in hope of success but to express their faith in the future.

Figure 1

CELL REQUIREMENTS

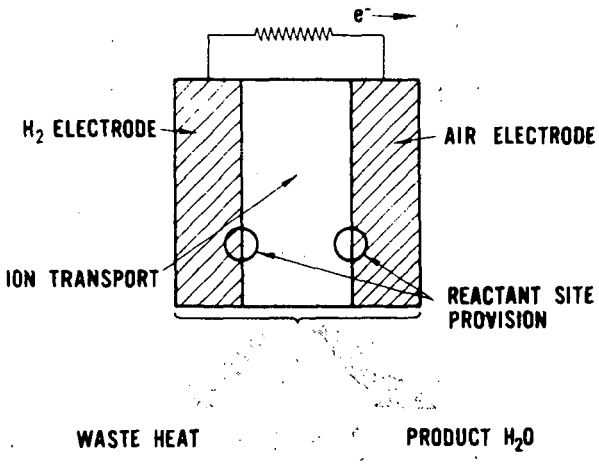

Figure 2

THE PROGRAM

OBJECTIVES

- DEVELOPMENT OF COMPETITIVE SYSTEM
- MANUFACTURING FACILITY
- TRAINED ORGANIZATIONS

ULTIMATE BENEFITS TO GAS INDUSTRY

- NEW LOADS
- LOAD LEVELER THROUGH BASE LOAD SENDOUT INCREASE
- COMPETITIVE ANSWER TO THE ALL ELECTRIC HOME

Figure 3

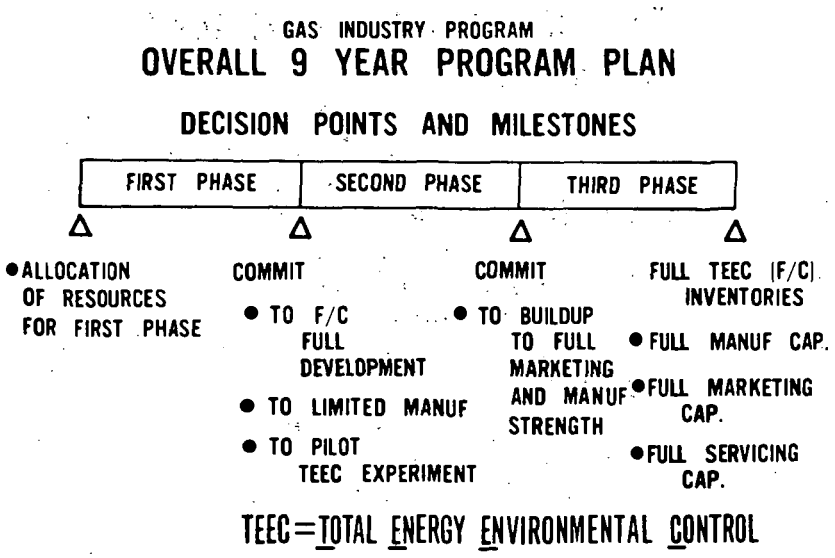

Figure 4

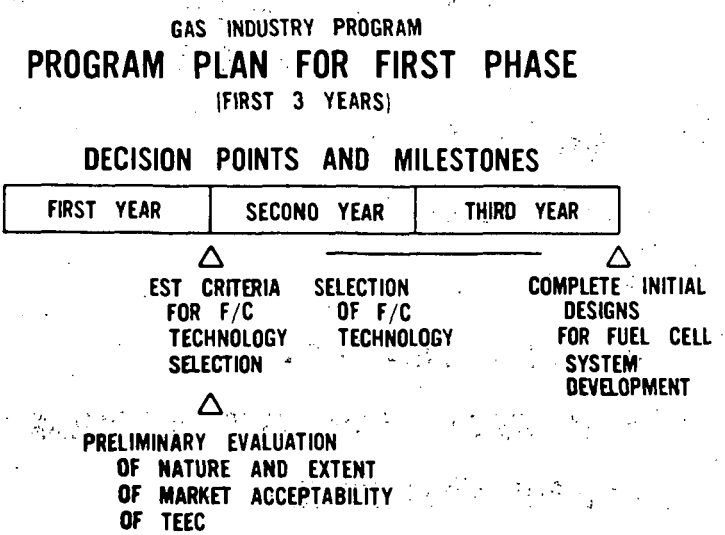

Figure 5

FUEL CELL POWERPLANT FEATURES

PERFORMANCE

- GOOD FUEL ECONOMY
- NO SIZE EFFECT ON CELL EFFICIENCY
- HIGH EFFICIENCY AT PARTLOAD

MODULAR PACKAGING

- MINIMUM OF DISSIMILAR PARTS
- SIMPLIFIED MAINTENANCE
- DEPENDABILITY
- INSTALLATION FLEXIBILITY

OPERATION

- SILENT & VIBRATION FREE
- CLEAN EXHAUST
- HEAT UTILIZATION
- FAST RESPONSE

Figure 6

GAS INDUSTRY PROGRAM

PROGRAM ELEMENTS

- MARKET ANALYSIS
- APPLICATIONS ANALYSIS
- SYSTEM ANALYSIS
- SYSTEM ENGINEERING
- TECHNOLOGY (BASIC AND POWERPLANT)
- APPLICATIONS TESTING

Figure 7

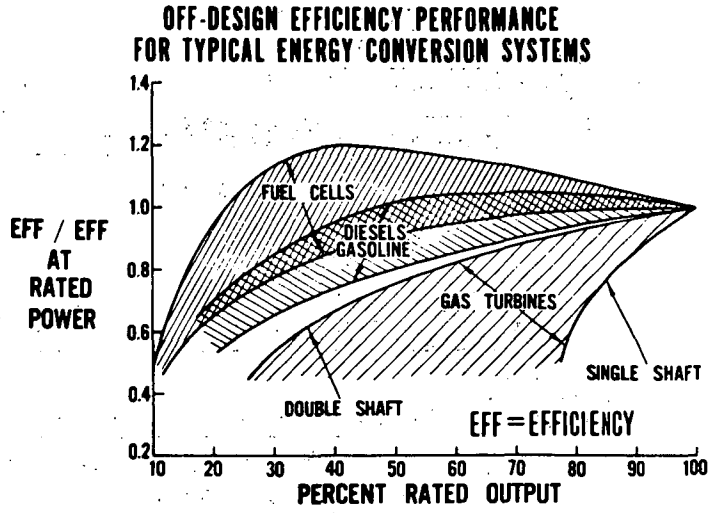

Figure 8

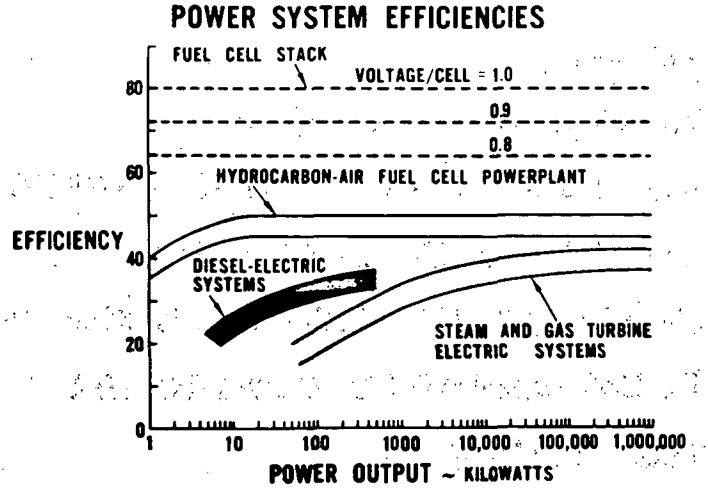

Figure 9

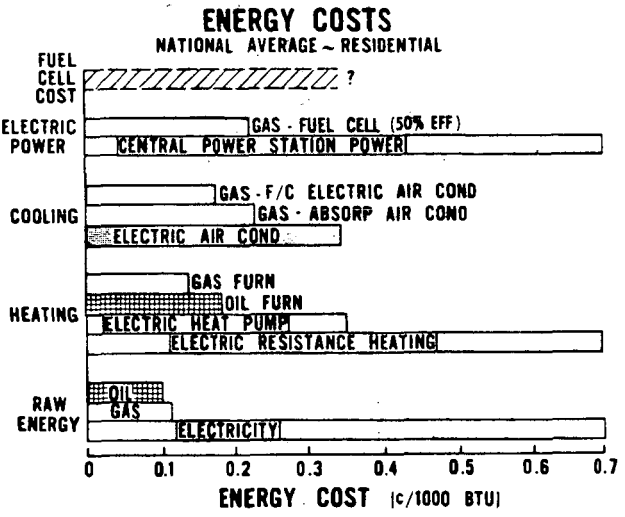

Figure 10

FUEL CELL – TOTAL ENERGY APPLICATIONS

- INDUSTRIAL
- MERCANTILE AND OFFICE BLDGS
- LARGE URBAN RESIDENTIAL (HI-RISE APARTMENT BLDG)
- LARGE HOTEL, HOSPITAL, DORMITORY
- SUBURBAN CONNECTED RESIDENTIAL (GARDEN APARTMENT)
- SUBURBAN DISCONNECTED RESIDENTIAL (TRACT)
- SINGLE RESIDENTIAL